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At the National Beef Quality Audit (NBQA) Strategy Workshop (hosted by the National Cattlemen's Association, March 18-20, 1992), workshop participants reviewed all of the information accumulated during the NBQA, and compiled a list of the 15 primary defects and(or) shortcomings of beef produced by slaughter steers and heifers (Smith et al., 1992). Listed first among the Top 15 concerns was **"low overall uniformity of beef"**, and listed sixth and seventh were **"low overall palatability"** and **"inadequate tenderness"**, respectively.

The following comments, recorded during the National Beef Quality Audit, provide insight into the industry's concern about the tenderness, quality and consistency of beef:

- *"Leanness, taste, tenderness price and consistency are keys to quality of beef".* (Nancy Yanish, Food Marketing Institute)
- *"The number 1 complaint of consumers of beef in restaurants is inconsistent tenderness".* (Stan Emerling, National Association of Meat Purveyors)
- *"Beef is now so variable [in tenderness], purveyors are having to jaccard or double-jaccard to remove variability".* (Marvin Walter, Carriage House Meat and Provision Company, Inc.)
- *"One of four beef steaks doesn't eat right..."* (Jens Knutson, American Meat Institute)

Evidence suggesting that the beef industry's concern about inadequate product tenderness is **real**, rather than **perceived**, was provided by the National Beef Tenderness Survey (Morgan et al., 1991). In the National Beef Tenderness Survey, a variety of beef retail cuts from the round, loin, rib and chuck were obtained from 8 to 12 supermarket stores in each of 14 major U.S. cities. Scientists at Texas A&M University then evaluated the tenderness of each cut using Warner-Bratzler shear force measurements and sensory panel analyses. Results of that study showed that 17.5% of rib and loin cuts, 40.8% of chuck cuts and 35.8% of round cuts had shear force values that were indicative of an "unacceptable" level of tenderness. Based on results of the National Beef Tenderness Survey, Morgan et al. (1991) concluded that, *"Steps must be taken throughout the beef industry to address the palatability variation issue".*

At the NBQA Strategy Workshop, Dr. Darrell Wilkes (Vice President, Research and Industry Information, NCA) outlined the consequences of presenting consumers with beef products that are dry, tough or unflavorful. According to data summarized by Dr. Wilkes: (a) only one-tenth of one percent of tough, dry or bland steaks are returned for replacement or refund; (b) for every one complaint that is vocalized, ten complaints are never heard; and ©)

most consumers who have a bad eating experience don't complain -- they just don't return (Smith et al., 1992). The potential for lost sales by the beef industry due to inadequate product tenderness is almost staggering when the number of consumers impacted by the production of a single "tough" carcass is considered. Harris and Savell (1993) estimated that *"the steaks and roasts from a single carcass could be consumed by 542 different consumers"*.

Current knowledge of the specific "cause and effect" mechanisms that determine whether a cut of beef is "tough" or "tender" is incomplete. However, intensive study continues to expand our understanding of tenderness differences and has shown that beef tenderness is influenced by a number of interacting antemortem and postmortem factors. The discussion below focuses on several factors known to affect beef tenderness and overall palatability, and outlines corrective action that could be taken with respect to each factor to improve the consistency of beef.

Marbling/Quality Grade. Among carcasses of the same maturity, USDA quality grade is determined by marbling score. Marbling scores and corresponding USDA quality grades (for A-maturity beef carcasses) are shown in Table 1.

Presently beef carcasses and(or) cuts are subdivided into four different marketing categories: (I) U.S. Prime - Cuts from Prime carcasses usually are merchandized in "white-table-cloth" restaurants or are exported to countries, such as Japan, that desire high-quality beef. (II) Upper 2/3 of U.S. Choice - Carcasses with Modest and Moderate marbling currently are identified for use in "high-quality" beef programs such as Certified Angus Beef, Sysco's Supreme Angus Beef, Monfort/ConAgra's Chef's Exclusive Beef or Excel's Sterling Silver Beef. Most of this beef is featured in restaurants, but some is sold at retail, and some also is exported. (III) Low Choice and Select - Carcasses in the lower 1/3 of U.S. Choice and the entire Select grade primarily are merchandized through supermarket chains. Although use of cuts officially graded Select continues to increase, a significant proportion of carcasses with Slight marbling still are merchandized through retail channels as "no-roll" (ungraded) beef. (IV) U.S. Standard - Carcasses in the Standard grade usually are marketed in one of two ways. Higher-end Standard carcasses usually are sold as "no-rolls" for the block beef trade, whereas the lower-end Standards may be boned for grinding beef. The current beef marketing system is structured so that price differences typically exist between each of the four categories described above, as well as between Low Choice and Select, within Category III.

Table 2 shows the quality grade distribution observed in the cooler audit phase of the NBQA. Also shown, for comparative purposes is the "desired" quality grade distribution which was established using the consensus opinion of participants in the NBQA Strategy Workshop.

According to results of the NBQA, current industry demand for high-quality beef exceeds supply, and production of Select and Standard grade beef exceeds demand. These data suggest that the industry should: (a) completely eliminate carcasses grading U.S. Standard, (b) increase production of carcasses with Modest and higher marbling scores, and ©) decrease, slightly, the production of carcasses grading U.S. Select.

Table 1. Marbling Scores and Quality Grades for A-Maturity Beef Carcasses Subdivided into Four Marketing Categories

Category	Marbling	Quality Grade	Primary Uses
I	Abundant Moderately Abundant Slightly Abundant	U.S. Prime	▸ Restaurant & Export
II	Moderate Modest	U.S. Choice (upper 2/3)	▸ Restaurant, Retail & Export
III	Small Slight	U.S. Choice (lower 1/3) U.S. Select	▸ Retail
IV	Traces Practically Devoid	U.S. Standard	▸ Retail (No-roll) ▸ Boneless Beef

Table 2. Actual and "Desired" Quality Grade Distributions -- National Beef Quality Audit

Quality Grade	Actual %	Desired %
Prime	2	7
Upper 2/3 of Choice	17	24
Low Choice	36	40
Select	37	29
Standard	8	0

Adapted from Smith et al. (1992).

It is noteworthy that the average external fat thickness of the carcasses sampled in the NBQA was .59 inch. This relatively high level of external fat, combined with a distribution of quality grades which was skewed toward the lower grades, reflects a low genetic propensity for marbling deposition in the U.S. cattle population. Correspondingly, to increase the supply of higher-quality beef without simultaneously increasing production of waste fat, cattlemen must

identify genetic strains of cattle that will deposit higher levels of marbling with relatively low levels of external finish. It also is of interest to note, that 20 percent of the cattle surveyed in the cooler audit phase of the NBQA had yield grades of 1 or 2 and quality grades of Choice or Prime, suggesting that it is possible to produce cattle with relatively high marbling levels, while maintaining acceptable carcass cutability (Hale, 1992).

Breed/Genotype. In general, research concerning the effects of breed on beef tenderness has shown that there is little difference in tenderness among breeds of *Bos taurus* cattle. However, beef produced by *Bos indicus* cattle usually is less tender than beef from *Bos taurus* cattle. Moreover, studies have shown that tenderness decreases as the percentage of *Bos indicus* breeding increases (Crouse et al., 1989). Recently, studies have shown that the tenderness differences commonly observed between *Bos taurus* and *Bos indicus* cattle are associated with differences in enzymatic tenderization which occurs during the normal aging period. During postmortem storage of fresh beef, proteolytic enzymes (the most important of which are called calcium dependent proteases or calpains) gradually break down structural proteins in the muscle, causing beef to become more tender with increased storage time. The calcium dependent proteases have an inhibitor (calpastatin) that limits their proteolytic activity. Several studies have shown that *Bos indicus* cattle have a higher activity of calpastatin than do *Bos taurus* cattle which causes their meat to undergo less tenderization during aging (Whipple et al., 1990, Wheeler et al., 1990). Recently, scientists at the U.S. Meat Animal Research Center have determined that calpastatin activity is highly heritable, and it is now believed that most of the tenderness differences that exist among breeds, and among strains within breeds, are related to genetic differences in Calpastatin activity (Morgan, 1992). Scientists at Utah State University (Dr. N.E. Muggli-Cockett) and Texas Tech University (Dr. R.D. Green) currently are using genetic markers for calpastatin to identify bovine genotypes that express differences in beef tenderness. Preliminary studies in these laboratories indicate that it may be possible in the future to utilize genetic screening techniques to select seedstock specifically for tenderness.

Until such tools become available, known differences in palatability traits among breeds or genotypes should be exploited. For example, during the past three years, researchers at Colorado State have conducted a series of studies for the American Hereford Association. Results of these studies have shown that straightbred Hereford cattle exhibit very few palatability problems and tend to be very consistent in tenderness. Huffhines et al. (1993) conducted a study to determine if cattle that exhibited phenotypic evidence of at least ½ Hereford breeding had palatability characteristics that were superior to those of commodity Choice and Select beef. Over 1,000 Hereford and Hereford-cross cattle (200 straightbred Hereford steers, 198 straightbred Hereford heifers, 203 Hereford x British steers, 200 Hereford x Continental steers, 200 Hereford x Brahman steers) were identified at a commercial feedlot for use in this study. To be selected for the study, cattle had to be fed 105 to 126 days, and had to appear no less than ½ Hereford. Following slaughter, carcasses produced by Hereford and Hereford-crossbred cattle, with 3.00 to 4.25% extractable crude fat in the ribeye (which included carcasses in the upper ½ of the Select grade and the lower 1/3 of the Choice grade) were segmented and designated as "Hereford Lean & Palatable" beef. Rib steaks from these carcasses were compared to commodity Choice and Select rib steaks using sensory evaluation and shear force determinations. Results of these comparisons are shown in Table 3.

Data presented in Table 3 demonstrate that efforts to reduce genetic variation and control differences in intramuscular fat content can result in significant improvements in palatability attributes of beef. A similar approach was used to develop a well-known and highly successful branded beef program -- Certified Angus Beef.

Table 3. Comparison of Palatabiltiy Traits of Rib Steaks Produced by "Hereford Lean & Palatable", Commodity Choice and Commodity Select Carcasses

Trait	"Hereford L & P"	Commodity Choice	Commodity Select
Tenderness	**5.29[a]**	**5.24[a]**	**4.78[b]**
Juiciness	**5.33[a]**	**4.97[b]**	**5.04[b]**
Flavor desirability	**5.38[a]**	**5.13[b]**	**4.93[c]**
Overall palatability	**5.20[a]**	**4.98[b]**	**4.65[c]**
Shear force, kg	**2.84[a]**	**3.12[b]**	**3.28[b]**

Adapted from Huffhines et al. (1993).

Time-On-Feed. Scientific evidence suggests that a minimum of 90 to 100 days on a high-concentrate finishing diet is necessary to assure acceptable beef tenderness and flavor (Tatum et al., 1980; Dolezal et al., 1982). From 1970 to 1991, the average number of days on feed for fed steers and heifers in the U.S. decreased from 180 to 134 days. As the average time-on-feed declines, the slaughter of "short-fed" cattle becomes more frequent. For example, this past Spring, slaughter lots with fewer that 90 days of grain feeding were commonplace.

As the retail and packing segments of the beef industry continue to lower fat trim specifications on primal, subprimal and retail cuts, cattle feeders likely will be encouraged to further reduce time-on-feed in an effort to decrease production of waste fat. If this occurs, then a minimum time-on-feed constraint of 90 days would assist in limiting further reductions in beef quality. If a time-on-feed constraint is impractical, as many in the industry believe, then perhaps a minimum fat thickness constraint could be used to achieve the same result. In a recent study at Colorado State, use of a minimum external fat thickness constraint of .20 inch was shown to be effective for improving tenderness ratings and reducing variation in tenderness of rib steaks, especially those from Select grade carcasses (Table 4).

Electrical Stimulation. Electrical stimulation (application of an electrical current to the pre-rigor beef carcass) has been shown to improve beef tenderness by 20 to 30%. Most of the research documenting improved tenderness as a result of electrical stimulation (ES), utilized high voltages ($\geq$ 400 volts). Today, ES is used routinely in the packing industry; however, due to government safety regulations, most plants use low-voltage ES ($\leq$ 50 volts).

Data collected during the past few years at Colorado State suggest that ES, as it presently is being used by the industry, probably has only a minimal effect on beef tenderness. Perhaps high-voltage ES should be re-evaluated as a means of reducing variation in beef tenderness.

Table 4. Tenderness Characteristics of Rib Steaks Showing the Effects of a Minimum Fat Thickness Constraint of 20 Inch for Carcasses Grading Select and Choice

		Tenderness rating		Shear force, kg	
Quality Grade	Fat thickness	Mean	Variance	Mean	Variance
Select	< .20 in.	4.50[b]	2.44[a]	3.05[a]	2.26[a]
Select	≥ .20 in.	5.26[a]	1.00[b]	2.70[b]	.39[b]
Choice	< .20 in.	5.33[a]	1.47[ab]	2.68[b]	1.11[a]
Choice	≥ .20 in.	5.31[a]	1.04[b]	2.42[c]	.34[b]

Adapted from Jones and Tatum (1993).

In a recent study at Colorado State University, use of ES at 240 volts was combined the normal stimulation routine used in a commercial plant (35 volts). The combined treatment significantly reduced early-postmortem muscle pH. In that study, lower pH values were associated with reduced variation in tenderness. Moreover, carcasses with longissimus pH values below 5.9 at 3 hours postmortem produced cuts that were similar in tenderness to cuts from the four major "high-quality" beef programs (Table 5). These data suggest that more effective use of ES could improve beef tenderness.

Table 5. Comparison of Lion Steaks Produced by Carcasses with 3-h Muscle pH Values Below 5.9 to Loin Steaks From "High-Quality" Carcasses

Trait	Carcasses with 3-h pH values ≤ 5.9	"High-Quality" Beef (Modest & higher marbling)
Tenderness	5.34[a]	5.58[a]
Shear force, kg	3.10[a]	2.89[a]

Adapted from Eilers et al. (1993).

Postmortem Aging. It has long been known that aging (postmortem refrigerated storage of fresh beef) is one of the most effective methods of tenderization. However, in today's retail beef industry, there is virtually no control over the length of the postmortem aging period. For

example, in the National Beef Tenderness Survey, the average aging time for beef cuts was 17 days; aging time ranged from 3 to 90 days (Morgan et al., 1991).

Research conducted recently at Colorado State suggests that aging for at least 12 days is critical for assuring acceptable tenderness of loin steaks, and that aging for 24 days provides assurance of acceptable tenderness of top sirloin and top round steaks. Use of these guidelines was shown to dramatically reduce the incidence of tenderness problems in the strip loin, top sirloin and round (Table 6).

Table 6. Effect of Length of the Postmortem Aging Period on the Incidence (%) of Steaks with "Unacceptable" Shear Force Values

Aging period	Strip loin	Top Sirloin	Top Round
6 days	39.1	59.4	50.0
12 days	9.4	37.5	18.8
18 days	12.5	34.4	18.8
24 days	12.7	15.9	9.5

"Unacceptable" shear force was defined as ≥ 3.9 kg for strip loin and top sirloin steaks, and ≥ 4.6 kg for top round steaks.

Adapted from Eilers et al. (1993).

Results of the National Beef Tenderness Survey suggest that aging does not eliminate all problems with tenderness. Despite relatively long average aging periods in that study, there still was a relatively high incidence of tenderness problems (Morgan et al., 1991). Some cuts apparently do not respond (in terms of tenderization) to longer aging periods, presumably because of higher than normal calpastatin activity, or inherently low proteolytic enzyme activities. Such cuts may require other methods of tenderization.

Scientists at the U.S. Meat Animal Research Center (Koohmaraie and co-workers) recently developed a method for tenderization of meat that involves infusion of a solution that contains calcium chloride. Addition of exogenous calcium into a muscle activates calcium dependent proteases and maximizes proteolysis. Infusion of meat with calcium chloride has been shown to increase tenderness by 30 to 40% (Morgan, 1992). In addition, calcium chloride infusion has been shown to improve tenderness of beef that normally does not respond well to aging (e.g., beef produced by *Bos indicus* cattle).

As indicated in the foregoing discussion, there are several corrective actions (some immediate, some long-term) that could be taken to improve the tenderness, quality and consistency of beef. Long-term, the beef industry's focus should be on reducing genetic variation in beef quality characteristics. The challenge to cattlemen is formidable, yet urgent. Dr. Darrell

Wilkes, in his address at the NBQA Strategy Workshop, outlined the beef producer's goal as follows:

> *"On any given day in the USA, 47% of our citizens are likely to 'eat-out' -- at a café or restaurant. If we really want as many as is possible of those who are eating-out to order beef, we must understand that 'Quality is Consistency'. The beef producer's goal must be the same as that of the cook, the restaurateur and the chef -- 100% consumer satisfaction".*

References

Crouse, J.D., L.V. Cundiff, R.M. Koch, M. Koohmaraie and S.C. Seideman. 1989. Comparisons of *Bos indicus* and *Bos taurus* inheritance for carcass beef characteristics and Meat Palatability. J. Anim. Sci. 67:2661.

Dolezal, H.G, G.C. Smith, J.W. Savell and Z.L. Carpenter. 1982. Effect of time-on-feed on the palatability of rib steaks from steers and heifers. J. Food Sci. 47:397.

Eilers, J.D., J.D. Tatum, J.B. Morgan and G.C. Smith. 1993. Modification of early-postmortem pH to produce beef with greater consistency in tenderness. Final Report submitted to the National Live Stock and Meat Board, Chicago, IL.

Hale, D.M. 1992. Low quality grades -- inadequate marbling. In: The final report of the National Beef Quality Audit -- 1991, pp. 167-172, Smith, G.C. (Ed.). Colorado State University, Fort Collins and Texas A&M University, College Station.

Harris, J.J. and J.W. Savell. 1993. Impact of carcass maturity on the tenderness of beef from young cattle. Backgrounder, Department of Animal Science, Texas A&M University, College Station.

Huffhines, C.P., G.C. Ledall, J.E. Cannon, J.D. Tatum, T.G. Field, M.A. Head, J.B. Morgan, R.P. Clayton, J.W. Wise and G.C. Smith. 1993. Carcass characteristics and cooked-steak palatability of straightbred Hereford steers and heifers and Hereford crossbred steers. J. Anim. Sci. 71(Suppl. 1):153.

Jones, B.K. and J.D. Tatum. 1993. Predictors of beef tenderness among carcasses produced under commercial conditions. J. Anim. Sci. (submitted).

Morgan, J.B., J.W. Savell, D.S. Hale, R.K. Miller, D.B. Griffin, H.R. Cross and S.D. Shackelford. 1991. National beef tenderness survey. J. Anim. Sci. 69:3274.

Morgan, J.B. 1992. Tenderness problems and potential solutions. In: The final report of the National Beef Quality Audit -- 1991, pp.180-187, Smith, G.C. (Ed.). Colorado State University, Fort Collins and Texas A&M University, College Station.

Smith, G.C., J.W. Savell, R.P. Clayton, T.G. Field, D.B. Griffin, D.S. Hale, M.F. Miller, T.H. Montgomery, J.B. Morgan, J.D. Tatum and J.W. Wise. 1992. The final report of the National Beef Quality Audit -- 1991. Colorado State University, Fort Collins and Texas A&M University, College Station.

Tatum, J.D., G.C. Smith, B.W. Berry, C.E. Murphey, F.L. Williams and Z.L. Carpenter. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. J. Anim. Sci. 50:833.

Wheeler, T.L., J.W. Savell, H.R. Cross, D.K. Lunt and S.B. Smith. 1990. Mechanisms associated with the variation in tenderness of meat from Brahman and Hereford cattle. J. Anim. Sci. 68:4206.

Whipple, G., M. Koohmaraie, M.E. Dikeman and J.D. Crouse. 1990. Predicting beef-longissimus tenderness from various biochemical and histological muscle traits. J. Anim. Sci. 68:4193.